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Notes on the identity of *Chrysothrix* populations (*Arthoniales, Ascomycota*) containing pinastric acid from southern and central California

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Abstract — *Chrysothrix xanthina* is reported new for coastal California from San Diego to Point Reyes. Notes on the taxonomy of *C. candelaris* and *C. xanthina* are provided. The differences in diameter of granules in published sources are also discussed.

Key words — *Chrysothricaceae*, chemotypes, pulvinic acid derivates, sterile lichens

Introduction

The lichen genus *Chrysothrix* Mont. (*Chrysothricaceae* Zahlbr., *Arthoniales* Henssen ex D. Hawksw. & O.E. Erikss.) consists of both sterile and fertile species. They are characterized by immersed or yellow to yellowish-green leprose ecorticate thalli with a chlorococcoid photobiont, immarginate or poorly marginate apothecia, ±*Arthonia*-type asci, and usually 3-septate hyaline ascospores. Most of the species contain pulvinic acid derivates or rarely usnic acid as the main secondary metabolites with additional substances, e.g. gyrophoric acid, diffractaic acid or terpenoids (Laundon 1981, Thor 1988, Tønsberg 1994, Kalb 2001, Elix & Kantvilas 2007, Harris & Ladd 2008, Ertz & Tehler 2010, Lendemer & Elix 2010).

Californian material of *Chrysothrix* species with thin, sorediate, indeterminate and unstratified thalli were included in the broad concept of *C. candelaris* (L.) J.R. Laundon by Tønsberg (2004) in his treatment of the Sonoran Desert Region. The chemistry of this material was given as 'calycin and/or pinastric acid' and the size of the granules as 12–30(–40) µm in diameter. According to the recent treatments of *Chrysothrix*, which included *C. xanthina* (Kalb 2001, Harris &

Ladd 2008), all of those records should rather be considered *C. candelaris* s.l., and may have included *C. xanthina*, a taxon recently resurrected from the synonymy of *C. candelaris* (Kalb 2001).

As it has not been clear to which species Californian material should be referred, we decided to revise the specimens from UCR to find out which of two taxa is actually present in southern and central California.

Material & methods

The studied material is deposited in BM and UCR with some duplicates in UGDA. Lichen substances were studied by thin-layer chromatography (TLC) according to the methods of Culberson & Kristinsson (1970) and Orange et al. (2001).

The species

Chrysothrix xanthina (Vain.) Kalb, Biblioth. Lichenol. 78: 144. 2001.

≡ *Lepraria xanthina* Vain., Cat. Afr. Pl. Welw. 2: 463. 1901.

Type: [ANGOLA] Hab. frequens ad Ficorum cortices prop Bango et Cambondo. Distr. Golungo Alto. Decbr. 1855, Welwitsch, Iter Angolense No. 447 (**lectotype**-BM!, selected by Laundon 1981: 110).

Morphological Characters — The species is characterized by a bright yellow or greenish yellow, thin and unstratified thallus consisting of more or less scattered soredium-like granules (functioning as vegetative propagules) reaching 25–40 µm in diameter (Kalb 2001, Harris & Ladd 2008). In the Californian specimens studied the granules were 20–40(–45) µm in diameter; sometimes the granules formed aggregations and those were larger (up to 80 µm in diameter).

Chemistry — Pinastric acid (major), vulpinic acid (minor or trace) and rarely traces of terpenoids (probably originating from bark) were detected in the studied specimens.

Comments — Kalb (2001) revised the concept of *Chrysothrix candelaris* s.l. and considered *C. xanthina* as a distinct species differing in having granules measuring 20–50 µm in diameter, the presence of pinastric acid as a major secondary compound, and tropical distribution. According to Kalb (2001) *C. candelaris* s.str., which occurs in temperate regions, is characterized by larger granules (75–200 µm in diam.) and the production of calycin as the major secondary compound. Rare tropical samples with calycin and temperate specimens with pinastric acid were also mentioned; the former material was considered as probably belonging to a distinct species.

Later *Chrysothrix xanthina* was reported from subtropical and temperate regions (up to the Canadian border) in eastern North America by Harris & Ladd (2008). Those authors also reported different granule measurements, 25–40 µm for *C. xanthina* and 50–75 µm for *C. candelaris* s.str. They also

discussed the pinastric acid chemotype of *C. candelaris* from Europe (which includes also the type of *Lepra citrina* Schaer.) and considered it as a chemical race of *C. candelaris* or a distinct species; in the latter case, *Lepra citrina* appears as the oldest available name. The North American material containing calycin that was otherwise similar to *C. xanthina*, was treated as *Chrysothrix* sp. (Harris & Ladd 2008).

The Californian material we studied contains pinastric acid (with minor or trace amounts of vulpinic acid) and has granules measuring 20–40(–45) µm in diameter. The size of the granules we observed is slightly smaller than previously reported for *Chrysothrix xanthina* by Harris & Ladd (2008), but perfectly falls into the variation reported by Kalb (2001); thus the specimens are referred to that species and this lichen is reported as new to California. Probably the specimens with pinastric acid, but with slightly smaller granules [12–30(–40) µm], reported by Tønsberg (1994) also belong to *C. xanthina,* but the relevant specimens need to be verified. The identity of material containing calycin from the Sonoran Desert Region also should be revised.

The size of the granules of *Chrysothrix xanthina* reported by Kalb (2001), Harris & Ladd (2008) and in this paper do not vary considerably and can be explained by intraspecific variation. Elix & Kantvilas (2007) reported *C. xanthina* as having granules 20–80 µm in diameter, but their measurements at least partly overlap those of specimens received from other areas. Most likely Elix & Kantvilas (2007) misinterpreted aggregations as simple granules; we also found some of those structures measuring up to 80 µm in diameter in our material, but closer examination showed they represented aggregations disintegrating into smaller granules. In the case of *C. candelaris*, however, one can see that the diameter of the granules shows much greater variation. The largest size, 75–200 µm in diam., was reported by Kalb (2001), while the smallest, (6–)12–25(–30) µm, by Tønsberg (1992), who however reported 3 chemotypes in that species. Harris & Ladd (2008) reported an intermediate size, 50–75 µm. This problem needs further study, including molecular techniques, of material from all areas within the range of *C. candelaris* s.l. to find out if it is one extremely variable species or a complex of poorly understood taxa.

On a rough surface such as a lichen, or when thalli of *Chrysothrix xanthina* are just beginning to develop on bark, sometimes clots of granules are formed, which could be mistaken for thalli of *C. granulosa* G. Thor. These however do not develop a medulla-like layer. Additionally *C. granulosa* differs in the production of calycin and diffractiac acid (Thor 1988, Tønsberg 2004).

Distribution and ecology — *Chrysothrix xanthina* is a widespread species in the tropics (Kalb 2001, Flakus et al. 2006), and it is the most common member of the genus in eastern North America (Harris & Ladd 2008) as well as common in Australia (Elix 2009). It is known also from Asia (Malaysia; Kalb

2001). Africa (Angola, Canary Islands, Madagascar, Kenya, Rwanda; Kalb 2001, Killmann & Fischer 2005) and Latin America (Bolivia, Brazil, Ecuador, Mexico, Paraguay, Venezuela; Kalb 2001, Nöske & Sipman 2004, Flakus et al. 2006). The information on its distribution in other parts of the world is uncertain. It is usually included in *C. candelaris* s.l. in areas where yellow leprose species on bark and rock have not been revised in modern times.

In the study area, *Chrysothrix xanthina* occurs along the coast of California from Point Loma in San Diego County to Point Reyes in Marin County. It is sympatric with *C. granulosa* along the coast. It also occurs farther inland, while *C. granulosa* is restricted only to the coast. No collections of *C. xanthina* were made over 300 meters in the study area, but in other areas it was found up to c. 3500 m a.s.l. (Kalb 2001, Flakus et al. 2006).

In California *Chrysothrix xanthina* is a pioneer, quickly becoming re-established in oak woodlands and chaparral that have burned. It is also a component of stable corticolous and lignicolous communities in undisturbed maritime chaparral, coast redwood forests, bishop pine forests, and native woodlands of Monterey Pine. It grows on a wide variety of phorophytes and wood, but also often on shaded rock and over saxicolous lichens. A mature population can form a thin and continuous beautiful yellow thallus covering the whole trunk of a tree.

Selected specimens examined — **U.S.A. California**. Los Angeles Co., Santa Monica Mountains, Rustic Canyon, on *Quercus agrifolia*. Knudsen 12063, T. Sagar (UCR); on bark of willows, Knudsen 12062, Sagar (UCR, UGDA-L 15948); upper Santa Ynez Canyon, Topanga State Park, on old bark of *Quercus agrifolia*, Knudsen 11790, Kocourková (UCR); Malibu Creek, on willow bark, Knudsen 11190, Sagar (UCR); Marin Co., Point Reyes National Park, Mount Vision, on *Pinus muricata*, Knudsen 9858.2, Kocourková (UCR); Monterey Co., Los Padres National Forest, Santa Lucia Mountains, Pacific Valley, on ocean bluffs, on volcanic outcrops and saxicolous lichens, Knudsen 11066 (UCR); Limekiln State Park, Hare Creek Trail, on coast redwood, Knudsen 10088 (UCR); San Diego Co., Mission Trails Regional Park, Oak Tree Loop, on *Malosma laurina* and *Quercus agrifolia*, Knudsen 10986 (UCR); Point Loma, on chaparral wood, Knudsen 8369, Compton (UCR); Torrey Pines State Park, on maritime chaparral, Knudsen 2687 (UCR); San Luis Obispo Co., Morro Bay State Park, White's Point, on boulder, Knudsen 4506, Andreano (UCR); Cambria, along Highway 1, on native *Pinus radiata*, Knudsen 12190 (UCR); Santa Barbara Co., Santa Cruz Island, Prisoner's Harbor, on volcanic rock, Knudsen 8584 et al. (UCR); Channel Islands National Park, Scorpion Canyon, on toyon tree, Knudsen 11917 (UCR); Santa Rosa Island, Channel Islands National Park, above mouth of Windmill Canyon, on wood, Knudsen 7853 (UCR, UGDA-L 15466); Wreck Road above Beecher's Bay, on rock, Knudsen 7512.2 (UCR); Ventura Co., Santa Monica Mountains, Point Mugu State Park, on *Quercus agrifolia*, Knudsen 11228, Sagar (UCR).

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